LOW DENSITY IRON BASED ALLOY FOR A GOLF CLUB HEAD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an iron based alloy for a golf club head, and more particularly to an iron based alloy that is formed by variations in the composition of the alloy and the operational conditions during the production process. The alloy has a low-density of less than 6.6 g/cm^3 and an excellent rust resistant property and is used to produce a golf club head.

2. Description of Related Art

Present conventional golf club manufacturing technology consists of two manufacturing methods, lost-wax casting and forging. Lost-wax casting starts with preparing a wax model. The wax model is coated alternately with a heatproof, siliceous slurry and dry sand or other dry aggregate several times. Then, the mold with the wax model is dried and heated to remove the wax to complete the mold. When producing a golf club head, melted liquid metal is poured into the mold to form the golf club head.

The forging process starts with preparing individual pieces of a golf club head, usually three pieces. The pieces of the golf head are welded together to form a complete golf club head that can be attached to a shaft. In addition to the two manufacturing methods, some club heads have a finish applied by surface plating, such as nickel-plating, cobalt-plating, diamond-plating or paneling treatment.

As shown in Table 1, the lost-wax casting method has the lowest manufacturing cost, but the forging method has more advantages than lost-wax

casting. A comparison of metallurgical characteristics of lost-wax casting and forging is listed in Table 2.

Table 1 – General Characteristics

Feature	Lost-wax Casting	Forging
Controllability	Low	Good
Sweet spot	Small	Big
Strike distance	Less	Farther
Variety of CG	Less	Good
Torque	Less	Big
Softness	Less	Middle
Accuracy	Less	Good
Stability	Less	Good

Table 2 – Metallurgical Characteristics

Mode	Code	Y.S. (Mpa)	U.T.S. (Mpa)	E.R. (%)	D ($10^3 kg/m^3$)	Hardness	Notes
Casting	17-4PH	611.8	864.9	23	7.8	HRc30	1030℃ 1Hour +720℃ 5Hour
	431SS	661.0	752.5	22	7.7	HRc20	720℃ 3hour
	255SS	682.1	110	14	7.8	HRc25	1060℃ 1Hour
	304SS	210.9	75	40	8.0	R_B88	1030℃ 1Hour
	Ti	436.0	492.3	18	4.5		Annealing
	Ti-6Al-4V	879.0	949.4	12	4.5		Melting and aging

Forging	304SS	225.0	506.3	64	7.9		Forging and annealing
	S25C	309.4	562.6	31	7.9	R_B82	
	Ti-6Al-4V	1075.9	1146.3	14	4.5	HRc36	
	455SS	1635.1	1716.6	13.28	7.8	HRc45	
	465SS	1760.6	1866.3	10.72	7.8	HRc51	

Clubs are either irons or woods. Generally speaking, a wood has an enlarged head with an inclined face and a longer shaft than an iron because the wood is usually used at a tee or to hit a ball a long distance. Golf clubs are categorized in the following groups based on the angle of the face and different lengths of the shaft,: driver, No. 1 wood; fairway driver or brassie, No. 2 wood; high-lofted wood or spoon, No. 3 and 4 woods; and approach wood or braffing spoon, No. 5, 7 and 9 woods;. A golfer selects a particular wood based on his or physical condition and preference.

The heads of conventional woods are made of wood, particularly persimmon. However, due to considering of resistance to corrosion, ductility and high ratio of strength to weight of the golf club heads, the wood in woods has been gradually replaced by metal alloys, usually, for example, pure titanium, 6-4 titanium alloy, SP700 titanium alloy, 15-3-3-2 titanium alloy, 2041 titanium alloy, 2205 two-phase stainless steel, 17-4PH stainless steel, AISI431, AISI455, AISI456, aero Al-Li alloy, Be-Cu alloy, etc. Wherein pure titanium, 6-4 titanium alloy, SP700 titanium alloy, 15-3-3-2 titanium alloy and 2041 titanium alloy are well known, expensive materials. Presently, metal alloys are more popular than wood in manufacturing of golf club woods.

A design tendencies with regard to woods is to improve the ability to successful hit a golf ball, and the designs tend to have the following features.

1. The heads of the clubs are enlarged to increase the size of the sweet spot on the face of the club and improve the probability of successfully hitting the golf ball. The volume of the woods can be from 280 c.c. to 310 c.c., and even as much as 350 c.c., and some irons are also formed with some oversized features, particularly such as having a large sweet spot to promote successfully hitting the golf ball and increasing the distance that the ball travels.

2. The center of gravity of the club head is lowered to increase the stability of the club head when striking of the ball, improve the point of contact on the club face and increase the distance the golf ball travels.

3. The shape of the club head is designed to have a streamlined face with low drag. To keep the striking stable and reduce the torque energy loss, the shape of the club head is designed in a computer to create the streamlined face on the club head to reduce the air-resisting coefficient and change the center of gravity and sweet spot of the club head.

The major elements of a golf club when performing a stress analysis are the striking surface, the sole and the club shaft. The striking surface or face of the golf head is the main stress point since it directly contacts the ball. The striking surface is usually 2.5~3.5mm thick. Durability and rigidity are basic requirements for the material of the striking surface. For a wood, the durability is mostly among 60~150ksi (N/mm^2). The sole is the bottom of the golf head, is a minor stress point of the golf club and is usually 3~5mm thick. Because the sole contacts the ground, basic requirements for the material of the sole are wear-

resistance, corrosion resistance and excellent strength. The shaft of the club flexes during the swing, absorbs shock transmitted through the club head and is made of metal or carbon fiber material.

Additionally, the governing bodies for golf have established standards for golf clubs. Consequently, the weight, density and strength of the material used in club heads are important factors in designing and manufacturing golf clubs.

Metallurgical properties and strength of metal alloy head for a conventional wood listed in Table 3. The best metal alloy head for a wood has a tensile strength of 60~155ksi, yield strength of 30~145ksi (1Mpa= 0.10205ksi), elongation rate of 12~64% and density of 4.5~8.0g/cm^3.

Table 3: Metallurgical properties and strength of metal alloy head.

Feature	Ti(JIS2)	Ti-6Al-4V	304	17-4PH	465	15-3-3-3
S.W. (10^3kg/m^3)	4.51	4.5	7.9	7.80	7.82	5.0
U.T.S (Mpa)	563.4	1146.3	506.3	864.9	1773.3	1221.3
Y.S (Mpa).	521.1	1075.9	225.4	611.8	1642.2	1117.8
S.S (10^4M)	1.249	2.549	0.64	1.109	2.268	2.442

In the recent one to two decades, metallurgical properties of Fe-Al-Mn based alloy have been found to be promoted by controlling the content and by performing heat treatment to obtain high strength and toughness, good resistance of low or high temperature and resistance to corrosion. The following papers have described these characteristics in detail.

"The Structure and Properties of Austenitic Alloys Containing Aluminum and Silicon" by D. J. Schmatz, Trans. ASM., vol. 52, p. 898, 1960;

"Phase Transformation Kinetics in Steel 9G28Yu9MVB" by G. B. Krivonogov et al., Phys. Met. & Metallog, vol. 4, p. 86, 1975;

"An Austenitic Stainless Steel without Nickel or Chromium" by S. K. Banerji, Met. Prog, p. 59, 1978;

"Phase Decomposition of Rapidly Solidified Fe-Mn-Al-C Austenitic Alloys" by J. Charles et al., Met. Prog., p. 71, 1981;

"New Stainless Steel without Nickel or Chromium for Alloys Applications" by R. Wang, Met. Prog, p. 72, 1983;

"New Cryogenic Materials" by J. Charles et al., Met. Prog, p. 71, 1981; and

"Electron Microscope Observation of Phase Decompositions in an Austentic Fe-8. 7 Al-29.7 M-1.04 C Alloy" by S. C. Tjong, Mater. Char, vol. 24, p. 275, 1990.

Reviewing the above noted references, manganese added to Fe-Al-Mn-C based alloy content has been found to stabilize the austenite structure and retain an FCC (face-centered cube) structure under room or lower than room temperature, which is beneficial to enhance the workability and ductility of the alloy. The aluminum content has a strong effect on oxidation resistance. The carbon content mainly helps precipitation of strengthening elements when the alloy is quenched rapidly after a solution heat treatment at a temperature from 1050°C to 1200°C, and then aged at a temperature from 450°C to 750°C. The alloy has a mono austenite structure during the quenching, and the fine $(Fe, Mn)_3AlC_x$ κ carbides are precipitated coherently within the austenite matrix during the aging. Additionally, after a lengthy aging, phase decomposition like $\gamma \rightarrow \alpha + \beta$-Mn or $\gamma \rightarrow \alpha + \beta$-Mn+$\kappa$ is produced on the grain boundary of the alloy

dependent on its chemical composition. The coarse precipitates of β-Mn will deteriorate the ductility of the alloy. Consequently, to obtain κ-phase carbides precipitated coherently within the austenite matrix and without the coarse β-Mn being precipitated is an important method for the alloy to possess satisfactory strength and ductility for the Fe-Al-Mn-C based alloy.

Fe-Al-Mn based alloys are found to mainly consists of iron with 5 to 12 wt % aluminum, 20 to 35 wt % manganese, 0.3 to 1.3 wt % carbon, and remaining weight of the alloy being iron. After being solution heat treated, quenched and aged, the Fe-Al-Mn based alloys will have different metallurgical properties dependent on their chemical compositions, a tensile strength in a range of 80 ksi to 200 ksi, a yield strength in a range from 60 ksi to 180 ksi and an elongation rate in a range from 62 % to 25 %. The chemical compositions and metallurgical properties of typical Fe-Al-Mn alloys, which have been studied by experts in this field, are listed in Table 4 and Table 5 for comparison.

Table 4: Fe-Al-Mn alloys

FeAlMn	Fe	Al	Mn	C	Other	Mechanical feature U.T.S (Mpa)	Y.S. (Mpa)	E.R. (%)	Notes
No.1	Bal.	5	30	0.3	0.1Nb	682.1	370.0	43	J.K. Han etc., Material science & Engineering, 91, 1987, pp73~79
No.2	Bal.	8	30	1.0		921.4	512.1	54	R.Wang etc., Metal progress, March 1983, pp72~76
No.3	Bal.	10	20	1.0		1020	777.1	44	
No.4	Bal.	5	20	1.0		842.8	419.3	59	
No.5	Bal.	8.5	30.1	0.88		874.2	455.7	58	H.J. Lai etc., J. of Material science 24, 1989.pp2449~2453
No.6	Bal.	8	30	1.0		921.4	514.2	54	D.J. Schmatz, Transactions of the ASM, 52, 1960,pp899
No.7	Bal.	6.72	21.28	0.55		870.0	433.5	62	S.J Chang etc., Wear science &Engineering, 91, 1987, pp73~79

No.8	Bal.	8.38	29.78	1.14		890.7	716.4	30	
No.9	Bal.	7.38	27.1	0.86	0.16Ti+ 0.1Nb	1321.4	1242.8	36.9	T.F. Liu, U.S. patent 4968357
No.10	Bal.	9.03	28.3	0.85		878.5	635.7	27.8	

Table 5: Fe-Al-Mn alloys

Code	Composition							
	Fe	Mn	Al	C	Ti	Cr	Si	Other
1	Bal.	29.50	7.85	0.97	0.38		0.90	
2	Bal.	28.42	7.93	0.93	0.75			
3	Bal.	30.15	7.95	1.04	0.96		1.29	
4	Bal.	29.51	7.82	1.06	1.51	6.04		
5	Bal.	30.25	7.95	0.96	2.05	6.15	1.01	
6	Bal.	29.20	7.89	0.92	2.50			
7	Bal.	29.45	8.96	1.09	0.51		1.11	
8	Bal.	28.52	9.02	1.05	1.72	6.98		
9	Bal.	29.53	8.87	0.98	2.09	5.52	1.23	
10	Bal.	29.13	9.98	0.94	2.01	6.06		
11	Bal.	27.10	7.38	0.86	0.16			0.10Nb
12	Bal.	28.30	9.03	0.85				
13	Bal.	28.46	4.11	0.74				
14	Bal.	28.65	8.02	0.98				
15	Bal.	29.98	9.28	1.01			2.01	
16	Bal.	29.05	9.34	0.82				
17	Bal.	28.97	8.23	0.81	0.52			
18	Bal.	30.19	9.53	1.32				
19	Bal.	29.39	8.25	1.09		8.77		
20	Bal.	29.45	9.77	1.08		3.82		

*Code 11, 12, 13, 14 are examples for comparison.

SUMMARY OF THE INVENTION

The main objective of the present invention is to provide a low density alloy for a golf club head. The alloy consists essentially of manganese,

aluminum, carbon, chromium, and selectively silicon, titanium and molybdenum. Wherein the composition of the alloy is 25 to 31 wt % manganese, 7 to 10 wt % aluminum, 0.9 to 1.1 wt % carbon, 0.8 to 1.5 wt % silicon, and 5 to 7 wt % chromium, 2 to 5 wt % titanium, 0.5 to 1 wt % molybdenum and the balance being iron. Due to the addition of chromium, titanium and molybdenum, the alloy has good resistance to corrosion. Additionally, the alloy has a density of less then 6.6 g/cm^3 after quenching and thermal treatment at 950~1270°C for 1~24 hours, even to 6.1 g/cm^3. A good finished surface quality is obtained after the alloy is forged at a temperature from 800°C to 1050°C. Furthermore, a combination of high ductility and high tensile strength is obtained after the alloy has been treated at a temperature from 980°C to 1080°C for 1 to 4 hours and then treated at a temperature from 500~650°C for 4~8 hours. Lastly, the alloy is cold rolled to change the crystalline grain structure of the alloy and is finished by age process. Therefore the low density alloy has high strength, high ductility and good resistance to corrosion, and a good surface finish quality is obtained to satisfy the requirements of the heads of golf clubs.

Further benefits and advantages of the present invention will become apparent after a careful reading of the detailed description with appropriate reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph of surface roughness of code 2 alloy obtained at different temperatures.

DETAILED DESCRIPTION OF THE INVENTION

An alloy in accordance with the present invention for heads of golf clubs essentially consists of iron, manganese, aluminum, carbon, chromium, and additionally silicon, titanium and molybdenum.

Specifically, the alloy contains 25 to 31 wt % manganese, 7 to 10 wt % aluminum, 0.9 to 1.1 wt % carbon, 5 to 7 wt % chromium, 0.8 to 1.5 wt % silicon, 2 to 5 wt % titanium, 0.5 to 1 wt % molybdenum, and the balance being iron.

As listed in the Table 5, alloys from code 1 to 10 are practicable embodiments having compositions within ranges of the present invention, and alloys from code 11 to 20 are used for comparison.

Now with reference to Table 6, an alloy of code 2 has been found to have a density of 6.596 g/cm^3, a tensile strength reaching 986 Mpa, a yield strength of 763.4 Mpa, a ductility of 38.5%, a density of 6.518 g/cm^3 after thermal treating at 1100°C for 2 hours. Then, the alloy of code 2 successfully undergoes both a 48-hour 5% salt spray test and a 3000-impact durability test.

Table 6:

Code	Mechanical properties							Notes
	U.T.S. (Mpa)	Y.S. (Mpa)	E.R. (%)	Density (g/cm^3)	Salt spray (48 hours)	Roughness Ra(μm)	Impact test (3000 particles)	
1	921.5	756.0	42.5	6.596	Fail	2.6	Pass	1. 950°C forging 2. 1000°C thermal treatment for 2 hours. 3. Code 3, 4 further has thermal treatment at 550°C for 1 hour. 4. Code 7 further has cold roller finishing.
2	986.0	763.4	38.5	6.518	Pass	2.6	Pass	
3	1137.4	855.6	28.1	6.453	Pass	2.9	Pass	
4	1197.4	935.6	21.1	6.437	Pass	2.8	Pass	
5	1147.4	955.6	14.1	6.206	Pass	2.6	Pass	
6	1247.4	895.6	10.1	6.273	Pass	2.8	Pass	
7	1891.8	1785.6	17.5	6.513	Pass	2.7	Pass	
8	1116.4	846.8	15.3	6.314	Pass	2.7	Pass	
9	1174.3	865.1	12.8	6.189	Pass	2.6	Pass	
10	1192.2	876.2	11.3	6.126	Pass	2.5	Pass	
11	1321.4	1242.8	36.9	6.771	Fail	2.4	Pass	
12	878.5	635.7	27.8	6.695	Fail	2.6	Pass	
13	621.6	459.0	47.0	7.217	Fail	2.5	Pass	
14	798.0	592.1	53.2	6.769	Fail	2.3	Pass	
15	810.6	618.1	9.8	6.647	Fail	2.5	Pass	
16	801.7	619.4	51.0	6.694	Fail	2.7	Pass	
17	793.0	593.1	51.2	6.517	Fail	2.5	Pass	
18	918.4	661.9	38.5	6.614	Fail	2.2	Pass	
19	934.5	632.9	37.5	6.738	Pass	2.7	Pass	
20	921.5	618.9	43.5	6.649	Fail	2.8	Pass	

*Code 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 are examples for comparison.

An alloy of code 6 in conformity with material standards for club heads has a density of 6.273 g/cm^3, a tensile strength reaching 1247.4 Mpa, a yield strength of 895.6 Mpa, a ductility of 10.1%, after thermal treating at 1100°C for 2 hours. Then, the alloy of code 6 successfully undergoes both a 48-hour 5% salt spray test and a 3000-impact durability test.

An alloy of code 7 possesses better mechanical properties than other

normal alloys and has a density of 6.513 g/cm^3, a tensile strength reaching 1891.8 Mpa, a yield strength of 1785.6 Mpa, a ductility reaching 17.5%, after roller treating at room temperature. Then, the alloy of code 7 successfully undergoes both a 48-hour 5% salt spray test and a 3000-impact durability test.

An alloy of code 11 disclosed by US patent No. 4968357 has a tensile strength of 1321.4 Mpa, a yield strength of 1242.8 Mpa, a ductility of 36.9% and a density of 6.871 g/cm^3.

An alloy of code 12 disclosed by US patent No. 4968357 has a tensile strength of 878.5 Mpa, a yield strength of 635.7 Mpa, a ductility of 27.8%, and a density of 6.695 g/cm^3.

The alloys of code 11 and code 12 each successfully underwent the 3000-impact test, but failed the 48-hour 5% salt spray test, and additionally their density exceeds the desired range of the invention.

An alloy of code 19 was found to have a tensile strength of 834.5 Mpa, a yield strength of 632.9 Mpa, a ductility of 37.5 % and a density of 6.738 g/cm^3, after having been treated for 4 hours at 1100°C. The alloy of code 19 successfully underwent both the 3000-impact test and 48-hour 5% salt spray test, but has a density that exceeds the desired range of the invention.

An alloy of code 20 was also found to have a tensile strength of 821.5 Mpa, a yield strength of 618.9 Mpa, a ductility of 43.5% and a density of 6.649 g/cm^3, after having been treated for 4 hours at 1100°C. The alloy of code 20 successfully underwent both the 3000-impact test and 48-hour 5% salt spray test, but has a density that exceeds the desired range of the invention.

With reference to Fig. 1, surface roughness of code 2 alloy increased

from 2.4 μm to 5.8 μm as the temperature of hot forging increased from 900°C to 1200°C. Therefore to meet the high quality requirement for golf clubs heads, the alloy must be hot forged below 1100°C to obtain a surface roughness (Ra) of less than 3 μm.

The chemical composition of the alloy should be strictly limited in accordance with the present invention, and the reasons for limiting each of the components follow.

Manganese is included and limited for the following reasons.

Manganese normally coexists with iron. Since manganese tends to combine with sulfur, the hot brittleness caused by the sulfur can be eliminated. Manganese also helps eliminate oxidates in the alloy. In high-carbon steel, manganese combines with carbon or iron to form Mn_3C and Fe_3C, denoted by $(Fe, Mn)_3C$, to increase the alloy's strength and hardness. When the alloy has a manganese content below 25 wt %, coarse iron grains are produced in the alloy during manufacturing, which is not beneficial to the workability and ductility of the alloy. If manganese content of the alloy is above 31 wt %, a large amount of the β-Mn phase is precipitated on the grain boundary, which results in brittleness of the alloy. Consequently, the manganese content of the alloy is strictly limited to between 25 wt % and 31 wt %.

Aluminum is included and limited for the following reasons.

Aluminum in an alloy has an excellent deoxydation effect, which not only depresses the growth of crystals to disperse the oxidates and nitrides, but also increases ductility, workability and toughness of the alloy. When the aluminum content of the alloy is less than 7.0 wt %, the yield strength decays to

less than the desired 55 ksi. When the aluminum content in the alloy rises above 10.0 wt %, the yield strength increases to more than a desired 70 ksi. Therefore, the aluminum content should be limited within the range of 7.0 wt % and 10.0 wt %.

Carbon is included and limited for the following reasons.

In addition to precipitating carbides, the carbon content works as a strengthening element to enhance the austenite structure. Coarse iron gains are reduced, and the austenite structure is stabilized by increasing the carbon content.

When the carbon content in the alloy exceeds 0.9 wt %, a stable austenite structure is formed in the alloy, which causes the yield strength to be in the desired range of 55~70 ksi. The carbon content should be limited within the range of 0.9 wt % to 1.1 wt %.

Chromium is included and limited for the following reasons.

With the inclusion of chromium in the alloy, the alloy possesses not only good resistance to corrosion and oxidation, but also good hardness and high temperature strength, and particularly increases durability of high-carbon steel.

When the chromium content of the alloy was below 5.0 wt %, heads made from the alloy failed the salt spray test. When the chromium content in the alloy exceeded 7.0 wt %, the elongation rate of the alloy dropped below a desired 65%. Therefore, the chromium content should be limited strictly within the range of 5.0 wt % to 7.0 wt %. If the chromium content is less then 5.0 wt %, the club head should be electroplated to enhance the resistance to corrosion.

Silicon is included and limited for the following reasons.

The silicon in the alloy eliminates formation of air holes and enhances contractibility and fluidity of the molten alloy steel. However, when the silicon content exceeds 1.5 wt %, the alloy is embrittled and the elongation rate is less then the desired 65%. Consequently, the silicon content of the alloy of the invention should be limited within a range of 0.8 wt % to 1.5 wt %, which helps in the casting process of the alloy.

Titanium is included and limited for the following reasons.

With addition of titanium to the alloy, the density of the alloy is reduced and the resistance to corrosion of the alloy is increased. When the titanium content of the alloy is below 0.35 wt %, the effect on density and resistance to corrosion are not significant. When the titanium content in the alloy exceeds 2.5 wt %, the elongation rate of the alloy is reduced. Therefore, limiting the titanium content of the alloy strictly within a range of 0.35 wt % and 2.5 wt % is beneficial to reduce density and increasing resistance to corrosion.

Molybdenum is included and limited for the following reasons.

With the addition of molybdenum to the alloy, the critical temperature of forming coarse austenite iron is raised to avoid tempering brittleness and to enhance high temperature strength, creeping strength and high temperature hardness. Furthermore, air holes are not easily formed in the alloy, and molybdenum carbide particles having excellent wear-resisting efficiency are precipitated. Moreover, addition of molybdenum also improves the fluidity of the molten alloy steel.

When the molybdenum content in the alloy is above 1.0 wt %, the molybdenum carbide particles are overly precipitated and cause brittleness of the

alloy. Therefore, the molybdenum content of the alloy limited strictly a range of 0.5 wt % to 1.0 % wt is beneficial to increasing fluidity of the molten alloy steel, casting capability and resistance to corrosion.

Overall, the alloy metal for making golf heads for woods can be hot forged at temperatures from 800°C to 1050°C, whereby the finished product will have an excellent surface roughness (Ra) of 3 μm. If the alloy is hot worked at a temperature from 1050°C to 1200°C, the alloy will have a surface roughness greater than 3 μm and an intensified oxide skin to reduce the quality of the golf head.

The alloy for golf heads for woods as described has the following advantages.

1. Appropriate metallurgical properties achieved. By controlling the content of aluminum, manganese and carbon, and adding a mechanical finishing process, the tensile strength increases to a range of 220 to 280 ksi, and yield strength increases to a range of 200 to 230 ksi.

2. Low density. By controlling the content of aluminum within 7.0~10.0 wt %, or adding titanium within 2.0~5.0 wt %, the alloy possesses an FCC structure to reduce the density of the alloy to 6.6~6.1 g/cm^3.

3. Resistance to corrosion. The alloy includes chromium, titanium and molybdenum, which increase the resistance to corrosion, and also reduce production cost of the heads of golf clubs.

The characteristic of the invention is to produce an alloy for a head of a golf club by suitable addition of alloying elements and by controlling heat treatment conditions. The alloy of the invention has a density of less than 6.6

g/cm3, a high ductility of less than 10%, a tensile strength within 220 ksi to 280 ksi, a yield strength within 200 ksi to 230 ksi and high resistance to corrosion. In accordance with the present invention, the mechanical properties of the alloy for heads of golf clubs are different from those of other recently developed alloys and more in conformity with the requirement of high strength, high ductility and resistance to corrosion of the heads of golf clubs.

It is to be understood, however, that the above illustration is only to clarify the feature of the alloy for making heads of golf clubs, and should not be deemed as the scope of the invention.